(54) Title: VEHICLE WHEEL INCORPORATING TIRE AIR PRESSURE SENSOR

(57) Abstract

A tire air pressure sensor (18) is mounted on a vehicle wheel (10) and includes an inertial mass (40) which is urged radially outwardly by centrifugal force resulting from rotation of the wheel (10). The tire air pressure is applied to the inertial mass (40) in opposition to the centrifugal force. When the rotational speed of the wheel (10) is sufficient that the centrifugal force overcomes the applied air pressure, the inertial mass (40) moves radially outwardly and opens a switch (33). The speed at which the switch (33) opens is a predetermined function of the tire pressure. In another embodiment (130), a second sensor (154, 160) is provided to sense when the tire pressure is below a minimum value. A spring (140) urges an inertial mass (138) inwardly in opposition to the centrifugal force, and the tire pressure is applied to a bellows (154) having an end (160) which moves radially outwardly in proportion to the applied pressure. The bellows (154) opens a first switch (166) when the pressure is higher than the minimum value, and the inertial mass (138) moves radially outwardly away from the end (160) of the bellows (154) to open a second switch (168) when the wheel speed exceeds the value corresponding to the tire pressure.

VEHICLE WHEEL INCORPORATING TIRE AIR PRESSURE SENSOR

BACKGROUND OF THE INVENTION
Field of the Invention

The present invention generally relates to the art of automotive vehicles, and more specifically to a wheel for
5   a vehicle incorporating a sensor for continuously monitoring the air pressure in a tire mounted on the wheel during operation of the vehicle.

Description of the Related Art

10   Low tire pressure is a primary cause of excessive fuel consumption, tire wear and impaired steerability. A normal tire will typically leak on the order of 25 percent of its pressure per year due to its inherent permeability. It is thus good practice to maintain tire pressure on a regular
15   basis.

However, even checking tire pressure every few weeks may not prevent these adverse affects when a slow leak is present, and the leak may go undetected unless a careful record is maintained of how frequently the pressure in each
20   tire has to be replenished. A fast leak or flat condition can rapidly cause damage to the tire and even render it unusable in a short period of time, but this condition may go unnoticed by an inexperienced driver until it is too late.

25   It is thus highly desirable to have some mechanism that automatically indicates to the driver when the tire

pressure is too low. One such system is disclosed in U.S. Patent No. 4,067,376 to Barabino. This patent discloses a high pressure air reservoir provided in the vehicle wheel, and a valve that automatically opens a passageway between

5   the high pressure reservoir and the tire in response to the tire pressure falling below a selected threshold level. In this manner, the tire pressure is automatically prevented from dropping below this level.

Although Barabino's system accomplishes its intended

10   purpose, the valve includes a complicated and expensive porting arrangement which limits its practical commercial application.

SUMMARY OF THE INVENTION

15   The present invention provides a vehicle wheel for mounting a tire thereon which incorporates a simple and inexpensive, yet accurate and reliable sensor for monitoring the air pressure in the tire.

More specifically, a tire air pressure sensor is

20   mounted on a vehicle wheel and includes an inertial mass which is urged radially outwardly by centrifugal force resulting from rotation of the wheel.

In a first embodiment of the invention, the tire air pressure is applied to the inertial mass in opposition to

25   the centrifugal force. When the rotational speed of the wheel is sufficient that the centrifugal force overcomes the applied air pressure, the inertial mass moves radially outwardly and opens a switch. The speed at which the switch opens is a predetermined function of the tire

30   pressure.

In a second embodiment of the invention, another sensor is provided to sense when the tire pressure is below a minimum value. A spring urges the inertial mass inwardly in opposition to the centrifugal force, and the tire

35   pressure is applied to a bellows having an end which moves

radially outwardly in proportion to the applied pressure.

The bellows opens a first switch when the pressure is higher than the minimum value, and the inertial mass moves radially outwardly away from the end of the bellows to open a second switch when the wheel speed exceeds the value corresponding to the tire pressure.

The present sensor may be used exclusively for indicating the tire pressure to the vehicle driver, or may be used to control a system such as disclosed by Barabino in which air is automatically fed from a high pressure reservoir into a tire when the sensed pressure drops below a certain value.

These and other features and advantages of the present invention will be apparent to those skilled in the art from the following detailed description, taken together with the accompanying drawings, in which like reference numerals refer to like parts.

DESCRIPTION OF THE DRAWINGS

FIG. 1 is a fragmentary cross sectional view illustrating a vehicle wheel and tire incorporating a tire air pressure sensor embodying the present invention;

FIG. 2 is a sectional view illustrating an embodiment of the sensor in which the tire air pressure is applied to a piston, and the wheel is stationary or rotating at a relatively low speed;

FIG. 3 is similar to FIG. 2, but illustrates the sensor with the wheel rotating at a relatively high speed;

FIG. 4 illustrates an embodiment of the sensor which is similar to that of FIGs. 2 and 3, but includes a rolling diaphragm for sealing the piston;

FIG. 5 illustrates an embodiment of the sensor in which the air pressure is applied to a bellows;

FIG. 6 illustrates an embodiment of the sensor including a second bellows for sensing when the tire air

pressure is below a minimum value;

FIG. 7 is an electrical schematic diagram illustrating a switch arrangement of the sensor of FIG. 6;

FIG. 8a illustrates an embodiment of the sensor including a single bellows for sensing the tire air pressure and for sensing when the pressure is below a minimum value, in which the pressure is below the minimum value;

FIG. 8b is similar to FIG. 8a, but illustrates the sensor with the pressure above the minimum value and the wheel stationary or rotating at a relatively low speed;

FIG. 8c is similar to FIG. 8a, but illustrates the sensor with the pressure above the minimum value and the wheel rotating at a relatively high speed; and

FIG. 8d is also similar to FIG. 8a, but illustrates the sensor with the pressure below the minimum value and the wheel rotating at a relatively high speed.

DETAILED DESCRIPTION OF THE INVENTION

As illustrated in FIG. 1, a wheel 10 for an automotive or other type of vehicle includes a rim 12 on which a tire 14 is mounted. The wheel 10 further includes a circular body or wall 16 which extends radially inwardly from the rim 12 and is formed with holes (not shown) for mounting the wheel 10 on an axle of the vehicle.

A tire air pressure sensor 18 embodying the invention is preferably fixed to the rim 12 inside the inflation space of tire 14. In this manner, the sensor 18 is exposed directly to the air pressure in the tire 14. However, it is within the scope of the invention, although not explicitly illustrated, to mount the sensor 18 on the wall 16 or at another location and provide a conduit for transmitting the tire air pressure to the sensor 18.

The sensor 18 is mounted with its sensitive axis coincident with a radial axis 20 which perpendicularly

intersects the rotational axis of the wheel 10. The radially outward direction along the axis 20 is indicated by an arrow 22. An electrical secondary winding or coil 24 is fixed to the wall 16 of the wheel 10 for integral rotation therewith. An electrical primary winding or coil 26 is fixed to a structural member 28 of the vehicle which does not rotate with the wheel 10. The coil 24 is proximate to the coil 26 and inductively coupled thereto at the illustrated rotational position of the wheel 10.

The structural member 28 and wheel 10 are electrically grounded. Both ends of the coil 26 are connected to a detector unit 30. One end of the coil 24 is grounded, and the other end is connected to the sensor 18 through a lead 32.

As illustrated in FIGs. 2 and 3, the sensor 18 includes a switch 33 which is connected between the lead 32 and ground. The switch 33 is in a first state (closed) at relatively low vehicle (tire rotational) speeds, and in a second state (open) at higher speeds. The detector unit 30 includes circuitry for detecting whether the switch 33 in the sensor 18 is open or closed. The impedance of the coil 24 is reflected back to the coil 26, and appears as a small load when the switch 33 is open, and as a high load when the switch 33 is closed.

The detector unit 30 may include an oscillator (not shown) for applying constant current pulses to the coil 26 and circuitry for sensing the voltage across the coil 26. The voltage will be lower when the switch 33 is closed than when the switch 33 is open. Alternatively, the detector unit 30 may apply constant voltage pulses to the coil 26 and sense the current through the coil 26. The current will be higher when the switch 33 is closed than when the switch 33 is open.

Alternatively, a capacitor (not shown) may be connected in parallel with the coil 24 to form a parallel resonant

circuit which oscillates in response to induced pulses from
the coil 26 when the switch 33 is open and does not
oscillate when the switch 33 is closed. The oscillation in
the coil 24 is reflected back to the coil 26 as a "ringing"
5   signal which can be detected by the detector unit 30.

The sensor 18 is illustrated in FIGs. 2 and 3, and
includes an electrically conductive housing or body 34
which is connected to ground. A bore 36 is formed in the
body 34 and extends along the axis 20. The radially inner
10   end of the bore 36 is closed, whereas the radially outer
end of the bore 36 communicates with the inflation space of
the tire 14 through a passageway 38.

An electrically conductive piston 40 which constitutes
an inertial mass is sealingly slidable in the bore 36 along
15   the axis 20. A pressure chamber 42 is defined in the bore
36 above a radially outer face 40a of the piston 40. The
pressure chamber 42 communicates with the inflation space
of the tire 14 through the passageway 38, such that the
pressure in the chamber 42 is the same as the pressure in
20   the tire 14.

Further illustrated are rubber or plastic o-rings 44
which fit in circumferential grooves 46 in the piston 40 to
enhance the seal between the piston 40 and the wall of the
bore 36. An electrically conductive projection 48 extends
25   from the radially inner end wall of the bore 36 toward a
radially inner face 40b of the piston 40. A conductive rod
49 extends through a bore formed through the central axis
of the piston 40 and is insulated from the radially outer
main body of the piston 40 by a sleeve 50 made of plastic
30   or other electrically insulative material. The rod 49 and
sleeve 50 are tightly fitted in the piston 40 and move
integrally therewith.

The rod 49 is electrically connected to the lead 32
which extends through an insulator 51 for insulating the
35   lead 32 from the body 34. The projection 48 constitutes a

first contact of the switch 33, whereas the rod 49 consti-
tutes a second contact thereof. In the position of FIG. 2,
the rod 49 contacts the projection 48 and the switch 33 is
closed. In the position of FIG. 3, the rod 49 is spaced
5   from the projection 48 and the switch 33 is open.

If the O-rings 44 effectively insulate the piston 40
from the body 34, it is possible to omit the rod 49 and
sleeve 50 and connect the lead 32 directly to the piston
40. However, the illustrated arrangement is preferred
10   since it enables the piston 40 to contact the body 34
without erroneously closing the switch 33. Such contact
might result from wear after prolonged operation of the
sensor 18.

The air pressure in the pressure chamber 42 acts on
15   the radially outer face 40a of the piston 40 and urges the
piston 40 radially inwardly opposite to the arrow 22. When
the vehicle is stationary or moving at a relatively low
speed, the rod 49 is held against the projection 48 by the
air pressure, and the switch 33 is closed. The radially
20   inward force Fin exerted on the piston 40 by the air
pressure in the chamber 42 is Fin = PA, where P is the air
pressure in the chamber 42 (the tire air pressure) and A is
the area of the face 40a of the piston 40.

Movement of the vehicle and rotation of the wheel 10
25   creates a centrifugal force Fout which urges the piston 40
radially outwardly in the direction of the arrow 22. The
force Fout = $4mrV^2/D^2$, where m is the mass of the piston 40,
r is the radial distance from the center of rotation of the
wheel 10 to the radially outer tip of the projection 48, V
30   is the linear speed of the vehicle and D is the diameter of
the tire 14.

When the centrifugal force Fout exerted on the piston
40 resulting from rotation of the wheel 10 exceeds the
force Fin exerted on the piston 40 by the pressure in the
35   chamber 42, the piston 40 and rod 49 move away from the

projection 48 and the switch 33 opens. The switch 33 opens
at Fout = Fin, or PA = $4mrV^2/D^2$, such that P = $(4mr/AD^2)V^2$.
Since m, r, A and D are constant, the tire air pressure P
varies as a predetermined function of vehicle speed V.
5   More specifically, the tire air pressure P is proportional
to the square of the vehicle speed V.

The vehicle on which the wheel 10 is mounted conven-
tionally includes a speedometer or tachometer for sensing
the vehicle speed V. The speed V at which the switch 33
10   opens is related to the tire pressure P in a precisely
predetermined manner, P = KV^2, where K = $4mr/AD^2$. The
detector unit 30 comprises a computing circuit, which may
be embodied by a conventional microprocessor or a dedicated
hardware unit, for computing the tire pressure P by
15   squaring the speed V and multiplying by the constant K.
The computed tire pressure P may be displayed on an
indicator on the vehicle control panel, or used to automat-
ically control the supply of air into the tire 14 if the
computed pressure is below a normal value such as 35 psi.

20   FIG. 4 illustrates a sensor 60 embodying the present
invention which is similar to the sensor 18 except that the
O-rings 44 are replaced by a rolling diaphragm 62 which is
commercially available, for example, from the Bellofram
company of Newell, West Virginia.

25   The central portion of the diaphragm 62 is clamped to
the outer face 40a of the piston 40 by an electrically
insulative face plate 64 and a screw 66, whereas the
periphery of the diaphragm 62 is fixed to the wall of the
bore 36 by an annular clamp 68. A folded or "rolling"
30   portion 62a of the diaphragm 62 extends into an annular
space 36a between the piston 40 and the wall of the bore
36. The lead 32 is connected to the screw 66, which is
threaded into and provides electrical connection to the rod
49.

35   The operation of the sensor 60 is essentially similar

to that of the sensor 18. The advantage of the rolling
diaphragm 62 over the O-rings 44 that the friction between
the piston 40 and the wall of the bore 36 is substantially
eliminated, and the sensor 60 is inherently more accurate
5   than the sensor 18.

In order to eliminate variation in the operation of
the sensor 60 which would result from changes in atmospher-
ic pressure if the section 36a of the bore 36 were vented
to the atmosphere, the section 36a is preferably sealed.
10 Under ideal conditions, the pressure in the section 36a
will remain constant at a known value.

The sensor 60 will operate accurately for an indefi-
nite period of time if the diaphragm 62 is made of a
material with low permeability. However, the permeability
15 of some rolling diaphragms which are commercially available
at low cost is sufficiently high that air from the chamber
42 can slowly permeate through the diaphragm 62 into the
section 36a. This will cause the pressure in the section
36a to gradually increase to the pressure in the chamber
20 42, rendering the sensor 60 inoperative.

This problem is overcome in a sensor 70 which is
illustrated in FIG. 5 and includes a body 72 formed with a
bore 74. An inertial mass 76, which provides the function
of the piston 40 described above, is disposed in the bore
25 74 for radial movement along the axis 20. The mass 76
includes an outer spool 78 which is formed with a bore 78a.
A stepped plug 80 is fitted inside the radially inner end
of the bore 78a. A flange 82 extends radially inwardly
from the radially outer wall of the body 72, and has a
30 passageway 84 formed therethrough which leads to the
inflation space of the tire 14.

A flexible, electrically conductive metal bellows 86
extends through the bore 78a, is fixed at its opposite ends
to the plug 80 and flange 82 respectively. A bellows 86
35 suitable for practicing the invention is commercially

available from the Servomotor company of Cedar Grove, New Jersey. The interior of the bellows 86 defines a pressure chamber 88 which provides the function of the pressure chamber 42 described above.

More specifically, the tire pressure is transmitted through the passageway 84 into the pressure chamber 88 and exerts a corresponding force on a radially outer face 80a of the plug 80. An elongated electrical feedthrough 90 extends through an insulator 92 into the bore 74. The lead 32 is connected to the feedthrough 90. The plug 80 is electrically connected to ground through the bellows 86, flange 82 and body 72 and constitutes one contact of a switch 91 which provides the function of the switch 33 described above. The feedthrough 90 constitutes a second contact of the switch 91.

The bellows 86 is flexible, and can have negligible resilience (spring rate or constant), or a predetermined value of resilience. In either case, the air pressure in the chamber 88 acts radially inwardly on the face 80a of the plug 80, whereas centrifugal force resulting from rotation of the wheel 10 acts radially outwardly on the inertial mass 76 which includes the spool 78 and plug 80.

When the centrifugal force is smaller than the force exerted by the pressure in the chamber 88, the radially inner face 80b of the plug 80 will engage with the feed-through 90 with the bellows 86 in the maximum extended position as illustrated, thereby closing the switch 91. When the centrifugal force overcomes the air pressure, the plug 80 moves away from the feedthrough 90, thereby opening the switch 91.

The bellows 86 is preferably made of a metal such as nickel which has extremely low permeability. Thus, substantially no air will leak from the chamber 88 into the bore 74 (external of the chamber 88), and the problem inherent in the sensor 60 which includes a low cost

permeable rolling diaphragm 62 does not exist in the sensor 70.

"Run-flat" tires have been recently introduced which retain their structural integrity and handling characteristics for 100 - 200 miles at zero tire pressure. This enables a vehicle with a punctured run-flat tire to be driven to a service facility without having to replace the punctured tire with a spare.

The sensors 18, 60 and 70 described above provide an accurate indication of tire pressure under normal operating conditions. However, they are unable to detect a sudden loss of tire pressure at high speed, such as caused by a puncture, since the switch is open at high speed and will remain open after the loss of pressure.

Since run-flat tires retain their handling characteristics at zero tire pressure, a vehicle operator might not discover that a run-flat tire has been punctured until it has been driven for a sufficient distance to cause damage to the tire and a potentially dangerous situation.

A sensor 100 illustrated in FIG. 6 is similar to the sensor 70 of FIG. 5, but includes an additional diaphragm and switch assembly for detecting when the air pressure in the tire 14 has dropped below a predetermined minimum value such as 15 psi. The sensor 100 includes a body 102, and elements common to the sensor 70 which are designated by the same reference numerals.

A bore 104 is formed in the body 102 which extends perpendicular to the axis 20. A flexible bellows 106 extends into the bore 104. A plug 108 is fitted in the left end (as viewed in FIG. 6) of the bellows 106, whereas the right end of the bellows 106 is supported by a flange 110. The tire pressure is transmitted to a pressure chamber 112 defined inside the bellows 106 through a passageway 114 formed through the flange 110. The bores 74 and 104 are interconnected by a passageway 115.

An electrical feedthrough 116 extends through an
insulator 118 which is fitted in a central hole in the
flange 110. The lead 32 is connected to the external end
of the feedthrough 116, whereas the internal portion of the
5   feedthrough 116 extends through the chamber 112 such that
the left end of the feedthrough 116 is adjacent to the plug
108. The plug 108 is connected to ground through the
bellows 106, flange 110 and body 102 and constitutes a
first contact of a low pressure sensing switch 120. The
10   feedthrough 116 constitutes a second contact of the switch
120.

Since the bellows 106 extends perpendicular to the
axis 20, it is substantially unaffected by centrifugal
force resulting from rotation of the wheel 10. In the
15   position illustrated, the pressure in the chamber 112 acts
on the inner face of the plug 108, urging the bellows 106
to extend until the plug 108 abuts against the left wall of
the bore 104. However, the bellows 106 is resiliently
extended in the illustrated position. The resilience of
20   the bellows 106 urges it to compress and move the plug 108
rightwardly against the force of the pressure in the
chamber 112.

The resilience (spring rate or constant) of the
bellows 106 is selected such that the bellows 106 will
25   compress to move the plug 108 rightwardly to engage with
the feedthrough 116 and close the switch 120 when the
pressure in the chamber 112 (tire pressure) is below the
predetermined minimum value. When the pressure rises above
the minimum value, it overcomes the resilience of the
30   bellows 106 and moves the plug 108 away from the feed-
through to open the switch 120.

A schematic diagram of the switches 91 and 120 is
illustrated in FIG. 7. When the tire pressure is below the
minimum value, for example 15 psi, the switch 120 will
35   remain closed at all vehicle speeds. Since the contacts 90

and 116 are both connected to the lead 32, the lead 32 will be connected to ground at all vehicle speeds in the low pressure condition.

Thus, if the vehicle is moving at a speed V which is sufficiently high that the switch 91 should be open (normal tire pressure) but the detector unit 30 senses that the lead 32 is grounded, the tire pressure must be below the minimum value. The detector unit 30 is constructed or programmed to indicate the low pressure condition when the vehicle is moving above a predetermined speed V and the lead 32 is grounded.

The following TABLE illustrates the logical function of the switches 91 and 120 in the sensor 100, assuming that the bellows 86 is resilient and urges the plug 80 toward contact with the feedthrough 90.

TABLE			
PRESSURE AND SPEED	SWITCH 91	SWITCH 120	LEAD 32
BELOW 15 PSI LOW SPEED	CLOSED	CLOSED	GROUNDED
BELOW 15 PSI HIGH SPEED	OPEN	CLOSED	GROUNDED
ABOVE 15 PSI LOW SPEED	CLOSED	OPEN	GROUNDED
ABOVE 15 PSI HIGH SPEED	OPEN	OPEN	OPEN

FIGs. 8a to 8d illustrate another sensor 130 embodying the invention which provides all of the functions of the sensor 100 but includes only one bellows. The sensor 130 includes a generally cup-shaped body 132 having a chamber 134 therein with a closed upper (as viewed in the

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drawing) end. The lower end of the chamber 134 is closed
by a flange 136. A generally cup-shaped inertial mass
138 is disposed in the chamber 134 for movement along the
axis 20, and is urged toward abutment with the flange 136
5   by a compression spring 140.

The mass 138 has a radially inwardly facing surface
138a on which a projection 142 is formed. An annularly
shaped insulator 144 extends radially outwardly from the
flange 136. An annular contact 146 extends radially
10   outwardly from the upper end of the insulator 144, and is
connected through a lead 148 to a feedthrough 150 extend-
ing through an insulator 152 which fits in a hole in the
body 132. The lead 32 is connected to the feedthrough
150, whereas the body 132 is grounded.

15   A resilient bellows 154 extends through a bore 156
formed through the flange 136 and insulator 144. The
interior of the bellows 154 is exposed to the tire pres-
sure and constitutes a pressure chamber 158. The radial-
ly outer end of the bellows 154 is sealed by an electri-
20   cally conductive end plate 160 which is connected to
ground through the bellows 154, flange 136 and body 132.
The mass 138 is connected to the feedthrough 150 through
the spring 140 and a lead 162. Further illustrated is an
insulator 164 which insulates the spring 140 and lead 162
25   from the body 132 and thereby from ground.

The contact 146 and plate 160 constitute a low
pressure switch 166 which provides the function of the
switch 120 described above. The projection 142 and plate
160 constitute a switch 168 which provides the function
30   of the switch 91 described above.

FIG. 8a illustrates the condition in which the
vehicle is stationary or moving at very low speed and the
tire pressure is below the minimum value. The resilience
of the bellows 154 is selected such that the bellows 154
35   will compress to move the plate 160 downwardly to engage

with the contact 146 and close the switch 166.

Whereas in the sensors described above the tire pressure acts in opposition to the centrifugal force resulting from rotation of the wheel 10, in the sensor 130 the tire pressure and centrifugal force both act radially outwardly. The spring 140 exerts a radially inward force on the mass 138 in opposition to the centrifugal force. In FIG. 8a, the centrifugal force is zero or very low, and the spring 140 moves the mass 138 downwardly so that the projection 142 contacts the plate 160 and closes the switch 168.

FIG. 8b illustrates the case in which the pressure is above the minimum value, and the vehicle is stationary or moving at very low speed. The pressure in the chamber 158 overcomes the resilience of the bellows 154 and the force of the spring 140 and moves the plate 160 away from the contact 146 to open the switch 120. However, the switch 168 is still closed by the force of the spring 140.

FIG. 8c illustrates the condition in which the tire pressure is above the minimum value and the vehicle is moving sufficiently fast that the centrifugal force acting on the mass 138 moves it radially outwardly against the force of the spring 140 and the projection 142 disengages from the plate 160 to open the switch 168. In this case, the switch 166 is also open such that the lead 32 is disconnected from ground.

The resilience of the bellows 154 is selected to be much higher than that of the spring 140. Thus, the radial position of the plate 160 will vary in accordance with the pressure in the chamber 158, with negligible effect from the spring 140. The plate 160 is moved progressively radially outwardly as the tire pressure increases and progressively compresses the spring 140 as long as the centrifugal force is insufficient to overcome

the force of the spring 140.

In this manner, the force exerted on the mass 138 by the spring 140 increases with tire pressure, and the centrifugal force and thereby the vehicle speed required

5   to overcome the spring force increases with tire pressure. The switch 168 thereby opens at a speed which increases with tire pressure in a predetermined manner as described above.

FIG. 8d illustrates the condition in which the

10   vehicle is moving at a speed which is high enough to open the switch 168 but the tire pressure is below the minimum value. In this case, the switch 166 is closed, and the low pressure condition is detected by the detector unit 30 as described above with reference to the TABLE.

15   While several illustrative embodiments of the invention have been shown and described, numerous variations and alternate embodiments will occur to those skilled in the art, without departing from the spirit and scope of the invention.

20   For example, the electrical switches described above which provide the outputs of the sensors can be replaced by pneumatic or other types of switches.

Accordingly, it is intended that the present invention not be limited solely to the specifically described

25   illustrative embodiments. Various modifications are contemplated and can be made without departing from the spirit and scope of the invention as defined by the appended claims.

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WE CLAIM:

1.   A sensor (18,60,70,100,130) for sensing the
pressure in a tire (14) which is mounted on a wheel (10),
comprising:

        inertial mass means (40)(78,80)(138) supported
5   by the wheel (10) for movement along a radial axis (20)
thereof, the inertial mass means (40)(78,80)(138) being
urged radially outwardly along said axis (20) by centrif-
ugal force resulting from rotation of the wheel (10);

        pressure transmitting means (36,38,40a,42)-
10   (36,38,42,62)(84,86,88)(154,156,158,160) for transmitting
said pressure from the tire (14) to the inertial mass
(40)(78,80)(138) means along said axis (20); and

        a switch means (33)(91)(168) which is actuated
by the inertial mass means (40)(78,80)(138) in response
15   to said centrifugal force and said pressure to a first
state when the rotational speed of the wheel (10) is
below a predetermined value which varies as a predeter-
mined function of said pressure, and to a second state
when said speed is above said predetermined value.

2.   A sensor (18,60,70,100) as in claim 1, in which
the pressure transmitting means (36,38,40a,42)(36,38,42,-
62)(84,86,88) transmits said pressure to the inertial
mass means (40)(78,80) radially inwardly along said axis
5   (20) in opposition to said centrifugal force.

3.   A sensor (18) as in claim 2, in which:
        the inertial mass means (40) comprises a piston
(40); and
        the pressure transmitting means (36,38,40a,42)
5   comprises:
            a radial bore (36) extending along said
axis (20) in which the piston (40) is sealingly slidable;

a pressure chamber (42) defined in said
bore (36) by a radially outer face (40a) of the piston
10   (40); and

a passageway (38) leading from the tire
(14) to the pressure chamber (42).

4.   A sensor (70,100) as in claim 2, in which the
pressure transmitting means (84,86,88) comprises a flexi-
ble bellows (86).

5.   A sensor (100) as in claim 4, further compris-
ing another flexible bellows (106) which extends perpen-
dicular to said axis (20) for sensing when said pressure
is below a predetermined minimum value and actuating the
5   switch means (91) to said first state in response there-
to.

6.   A sensor (60) as in claim 1, in which:
the inertial mass means (40) comprises a piston
(40); and
the pressure transmitting means (36,38,42,62)
5   comprises:
a radial bore (36) which extends along
said axis (20) and has an inner surface;
a rolling diaphragm (62) having a radially
outer periphery which is sealingly fixed to said surface;
10   a pressure chamber (42) which is sealingly
defined in said bore by a radially outer face of the
diaphragm; and
a passageway (38) leading from the tire
(14) to the pressure chamber (42); in which
15   the piston (40) is movable in said bore (36)
and has a radially outer end (40a) which is fixed to a
radially inner face of the diaphragm (62).

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7.   A sensor (18,60,70,100) as in claim 1, in which
the switch means (33)(91) comprises:
        a movable contact (49)(80) which is integral
with a radially inwardly facing surface (40b)(80b) of the
5   inertial mass means (40)(78,80); and
        a fixed contact (48)(90) which is disposed
radially inwardly of and is engageable with the movable
contact (49)(80).

8.   A sensor (100)(130) as in claim 1, further
comprising low pressure sensing means (106,120)(154,166)
for sensing when said pressure is below a predetermined
minimum value and actuating the switch means (91)(168) to
5   said first state in response thereto.

9.   A sensor (100) as in claim 8, in which the low
pressure sensing means (106,120) comprises a flexible
bellows (106) which extends perpendicular to said axis
(20).

10.   A sensor (130) as in claim 1, in which said
pressure transmitting means (154,156,158,160) transmits
said pressure to the inertial mass means (138) radially
outwardly along said axis (20).

11.   A sensor (130) as in claim 10, further compris-
ing biasing means (140) for urging the inertial mass
means (138) radially inwardly along said axis (20).

12.   A sensor (130) as in claim 11, in which the
pressure transmitting means (154,156,158,160) comprises a
resilient bellows (154) which extends along said axis
(20) and has a movable radially outer end portion (160)
5   which is engageable with a radially inwardly facing
portion (142) of the inertial mass means (138).

13. A sensor (130) as in claim 12, in which the
bellows (154) has a spring rate which is higher than the
spring rate of the biasing means (140) such that the
radial position of said outer end portion (160) of the
5   bellows (154) varies as a predetermined function of said
pressure.

14. A sensor (130) as in claim 13, in which the
switch means (168) comprises:
        a first movable contact (160) which is integral
with said outer end portion (160) of the bellows (154);
5   a fixed contact (146) which is disposed radial-
ly inwardly of and is engageable with the first movable
contact (160); and
        a second movable contact (142) which is inte-
gral with said inwardly facing portion (142) of the
10   inertial mass means (138) and is engageable with the
first movable contact (160).

15. A sensor (130) as in claim 14, in which the
fixed contact (146) and the second movable contact (142)
are electrically interconnected.

16. A vehicle wheel (10) comprising:
        a body (16) having a peripheral rim (12) for
mounting a tire (14) thereon, said rim (12) and said tire
(14) defining a pressurized inflation space;
5   an inertial mass means (40)(78,80)(138) which
is integrally rotatable with the body (16) and movable
along a radial axis (20) of the wheel (10), the inertial
mass means (40)(78,80)(138) being urged radially outward-
ly along said axis (20) by centrifugal force resulting
10   from rotation of the wheel (10);
        pressure transmitting means (36,38,40a,42)-
(36,38,42,62)(84,86,88)(154,156,158,160) for transmitting

the pressure in said inflation space to the inertial mass
means (40)(78,80)(138) along said axis (20); and

15   a switch means (33,91,168) which is actuated by
the inertial mass means (40)(78,80)(138) in response to
said centrifugal force and said pressure to a first state
when the rotational speed of the wheel (10) is below a
predetermined value which varies as a predetermined
20   function of said pressure, and to a second state when
said speed is above said predetermined value.

    17.   A wheel (10) as in claim 16, in which the
pressure transmitting means (36,38,40a,42)(36,38,42,62)-
(84,86,88) transmits said pressure to the inertial mass
means (40)(78,80) radially inwardly along said axis (20)
5   in opposition to said centrifugal force.

    18.   A wheel (10) as in claim 17, in which:
            the inertial mass means (40) comprises a piston
(40); and
            the pressure transmitting means (36,38,40a,42)
5   comprises:
            a radial bore (36) extending along said
axis (20) in which the piston (40) is sealingly slidable;
            a pressure chamber (42) defined in said
bore (36) by a radially outer face (40a) of the piston
10   (40); and
            a passageway (38) leading from the tire
(14) to the pressure chamber (42).

    19.   A wheel (10) as in claim 17, in which the
pressure transmitting means (84,86,88) comprises a flexi-
ble bellows (86).

    20.   A wheel (10) as in claim 19, further comprising
another flexible bellows (106) which extends perpendicu-

lar to said axis (20) for sensing when said pressure is
below a predetermined minimum value and actuating the
5   switch means (91) to said first state in response there-
to.

21.   A wheel (10) as in claim 17, in which:
the inertial mass means (40) comprises a piston
(40); and
the pressure transmitting means (36,38,42,62)
5   comprises:
a radial bore (36) which extends along
said axis (20) and has an inner surface;
a rolling diaphragm (62) having a radially
outer periphery which is sealingly fixed to said surface;
10   a pressure chamber (42) which is sealingly
defined in said bore by a radially outer face of the
diaphragm; and
a passageway (38) leading from the tire
(14) to the pressure chamber (42); in which
15   the piston (40) is movable in said bore (36)
and has a radially outer end (40a) which is fixed to a
radially inner face of the diaphragm (62).

22.   A wheel as in claim 16, in which the switch
means (33)(91) comprises:
a movable contact (49)(80) which is integral
with a radially inwardly facing surface (40b)(80b) of the
5   inertial mass means (40)(78,80); and
a fixed contact (48)(90) which is disposed
radially inwardly of and is engageable with the movable
contact (49)(80).

23.   A wheel (10) as in claim 16, further comprising
low pressure sensing means (106,120)(154,156) for sensing
when said pressure is below a predetermined minimum value

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and actuating the switch means (91)(168) to said first
state in response thereto.

24. A wheel (10) as in claim 23, in which the low
pressure sensing means (106,120) comprises a flexible
bellows (106).

25. A wheel (10) as in claim 16, in which said
pressure transmitting means (154,156,158,160) transmits
said pressure to the inertial mass means (138) radially
outwardly along said axis (20).

26. A wheel (10) as in claim 25, further comprising
biasing means (140) for urging the inertial mass means
(138) radially inwardly along said axis (20).

27. A wheel (10) as in claim 26, in which the
pressure transmitting means (154,156,158,160) comprises a
resilient bellows (154) having a movable radially outer
end portion (160) which is engageable with a radially
inwardly facing portion (142) of the inertial mass means
(138).

28. A wheel (10) as in claim 27, in which the
bellows (154) has a spring rate which is higher than the
spring rate of the biasing means (140), such that the
radial position of said outer end portion (160) of the
bellows (154) varies as a predetermined function of said
pressure.

29. A wheel (10) as in claim 28, in which the
switch means (168) comprises:
        a first movable contact (160) which is integral
with said outer end portion (160) of the bellows (154);
        a fixed contact (146) which is disposed radial-

ly inwardly of and is engageable with the first movable
contact (160); and

        a second movable contact (142) which is inte-
gral with said inwardly facing portion (142) of the
10   inertial mass means (138) and is engageable with the
first movable contact (160).

    30. A wheel (10) as in claim 29, in which the fixed
contact (146) and the second movable contact (142) are
electrically interconnected.

    31. A wheel (10) as in claim 16, further comprising
a housing (34)(72)(102)(132) which is fixed to said rim
(12) inside said inflation space, the inertial mass means
(40)(78,80)(138) and pressure transmitting means (36,38,-
5   40a,42)(36,38,42,62)(84,86,88)(154,156,158,160) being
disposed in said housing (34)(72)(102)(132).
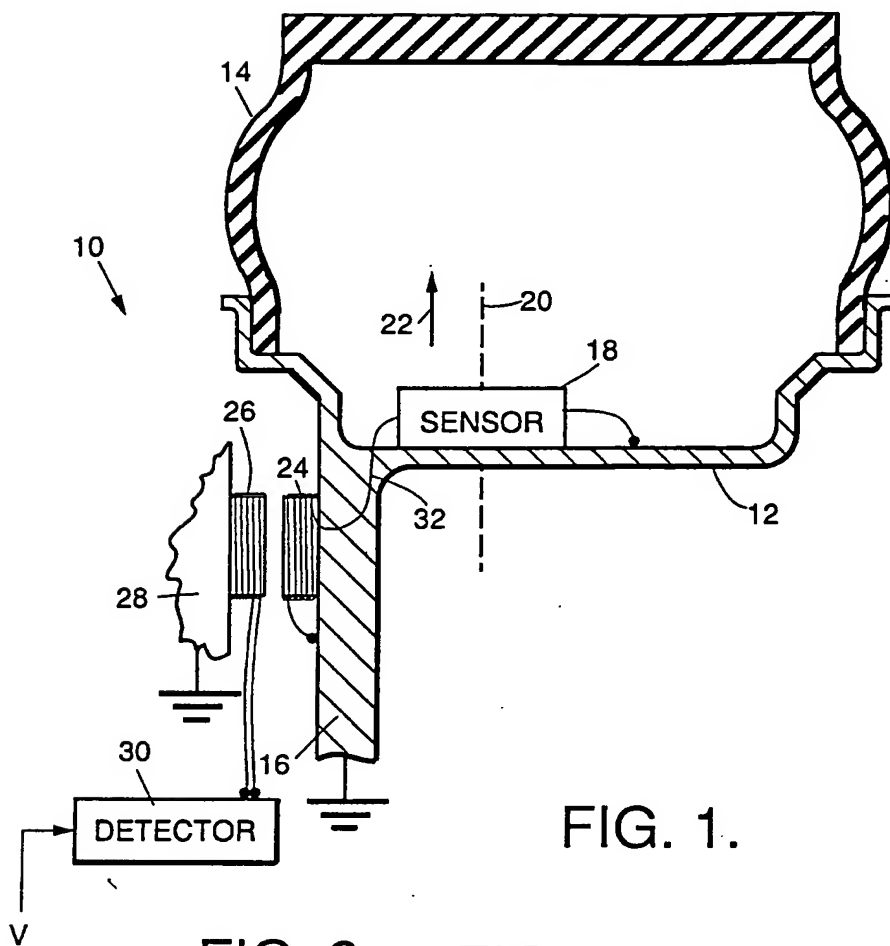
FIG. 1.
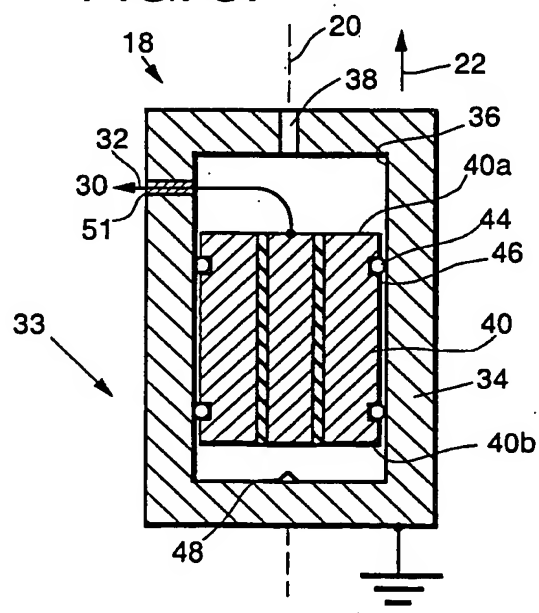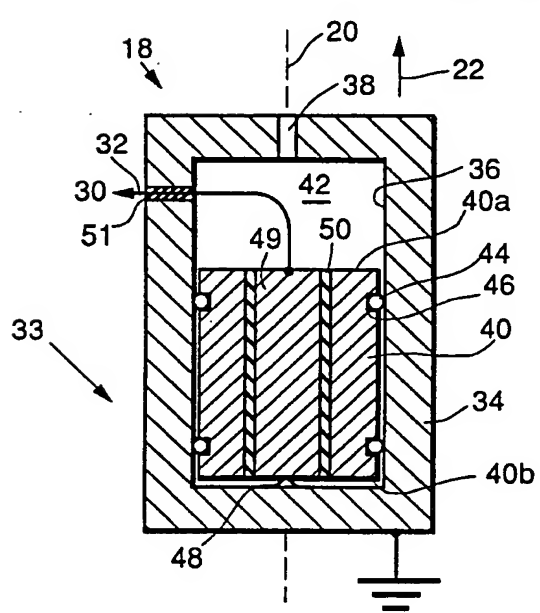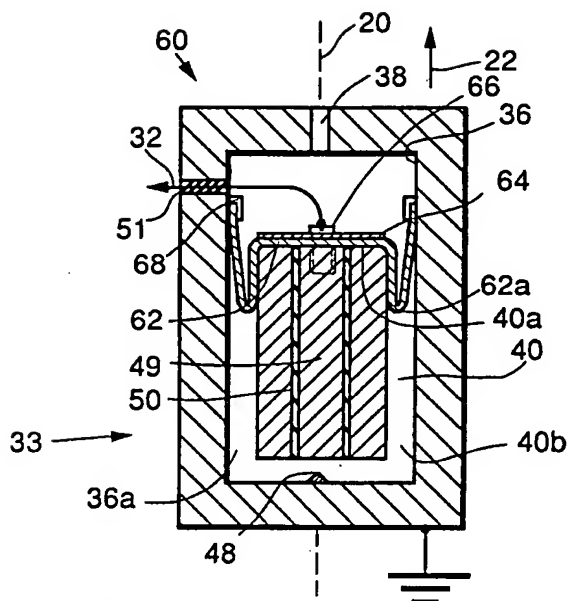
FIG. 2.   FIG. 3.

FIG. 4.

FIG. 5.

FIG. 6.

FIG. 7.
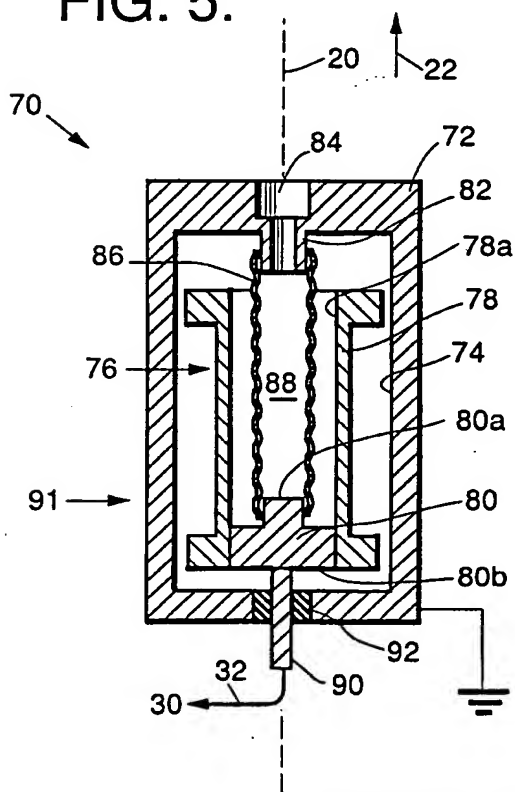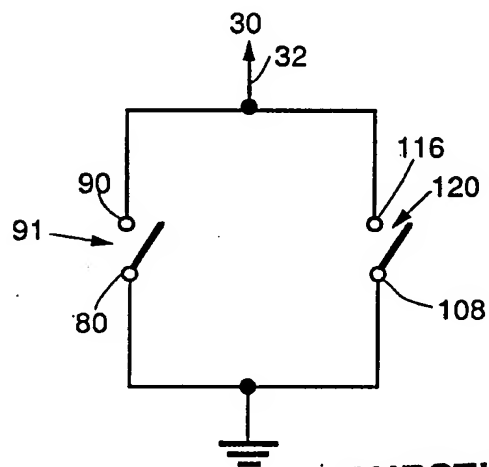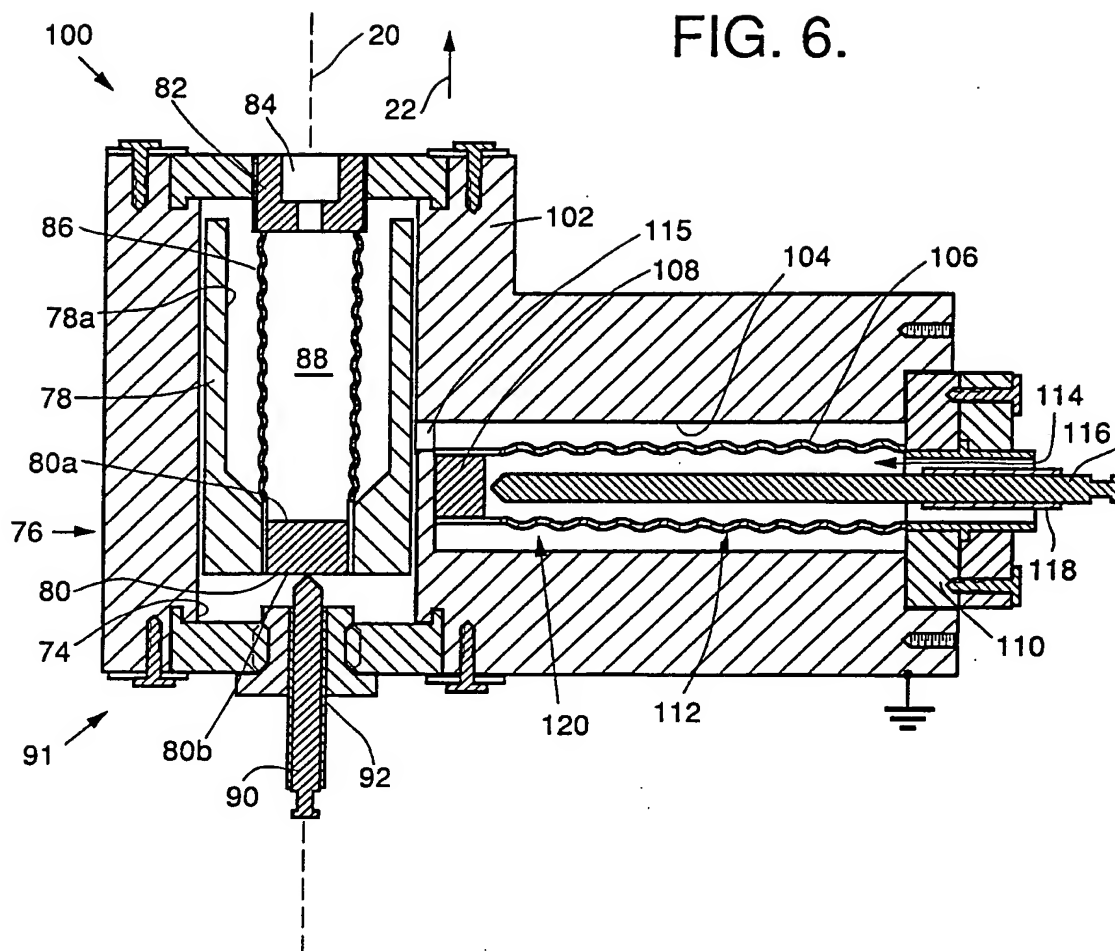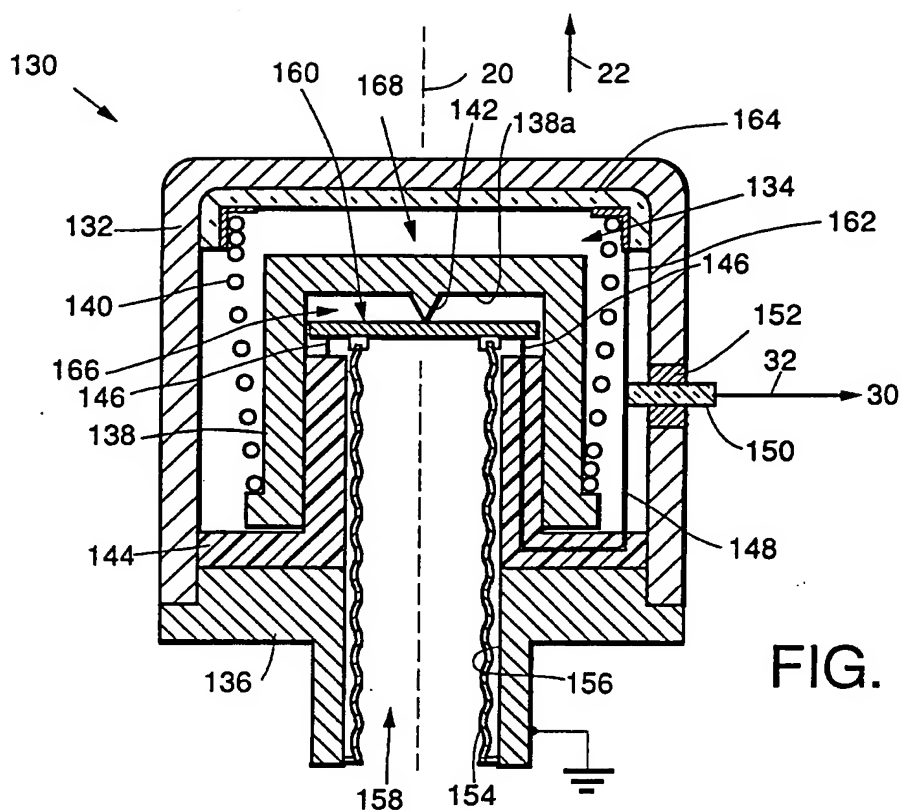
FIG. 8a.
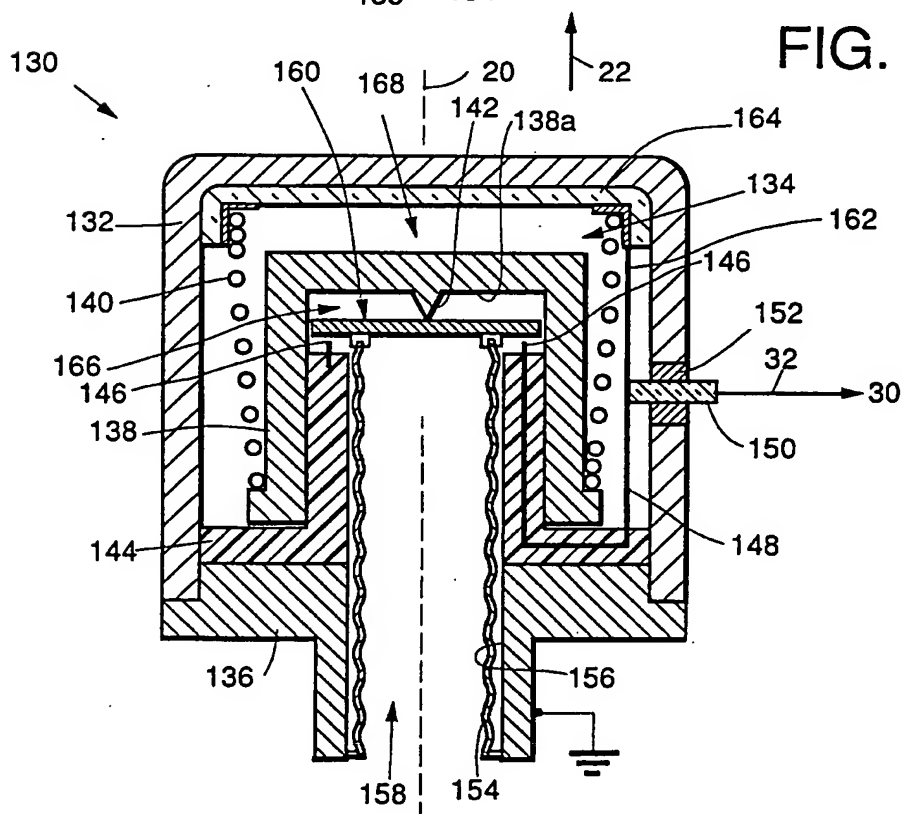
FIG. 8b.
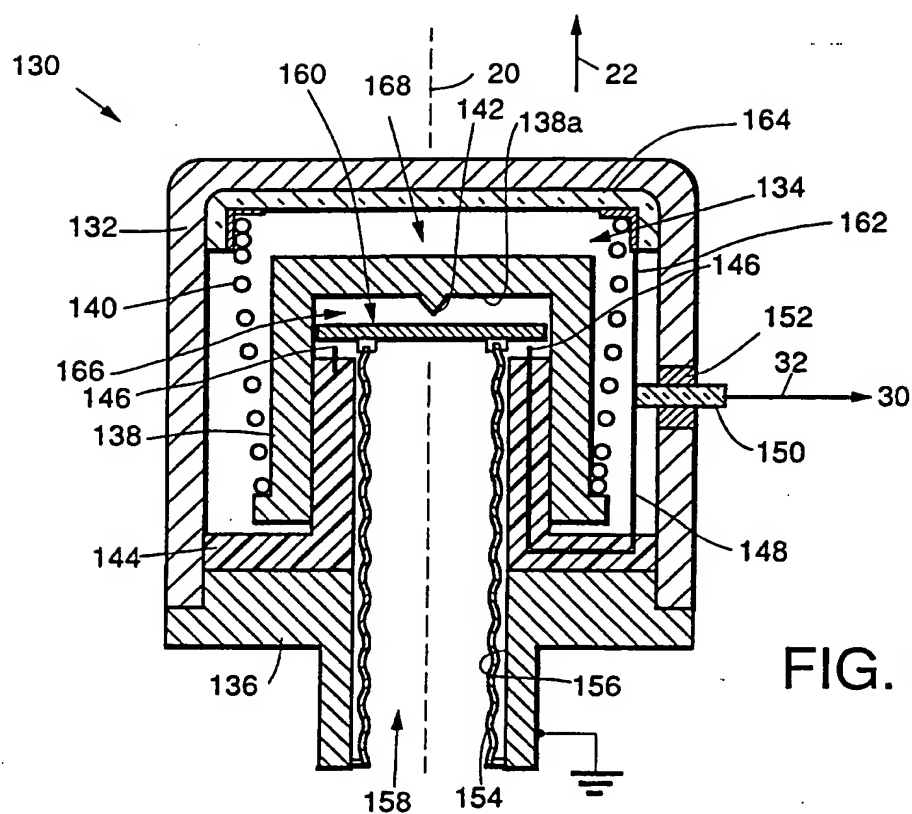
FIG. 8c.
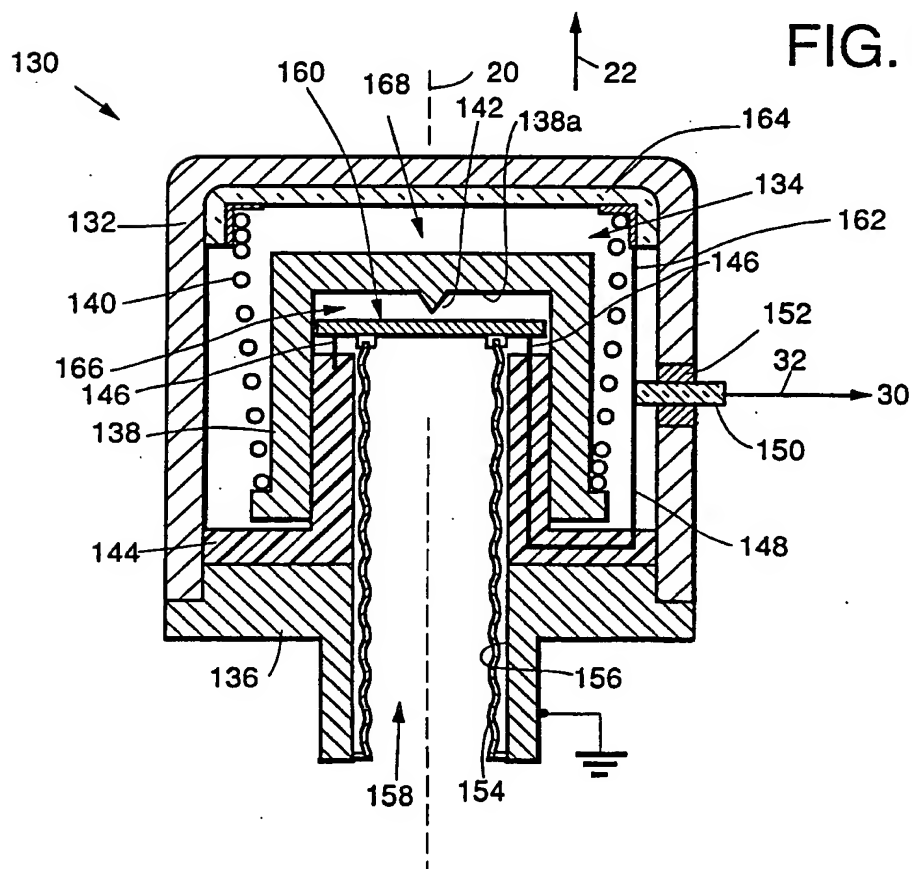
FIG. 8d.

International Application No

PCT/US 93/09236

A. CLASSIFICATION OF SUBJECT MATTER
IPC 5   B60C23/04

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED
Minimum documentation searched (classification system followed by classification symbols)
IPC 5   B60C

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	WO,A,90 00984 (BOSCH) 8 February 1990 see claim 1; figures ---	1,2,4, 16,17,19
X	EP,A,0 335 082 (PORSCHE) 4 October 1989 see column 2, line 4 - column 3, line 25; figures ---	1,2,4, 16,17, 19,31
A	US,A,3 710 314 (BELL) 9 January 1973 see column 4, line 6 - line 65; figure 1 ---	4,6
A	DE,A,37 14 007 (VDO) 10 November 1988 see column 5, line 42 - column 6, line 6; figure 6 ---	4,7
	-/--	

[X]	Further documents are listed in the continuation of box C.		[X]	Patent family members are listed in annex.

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Date of the actual completion of the international search	Date of mailing of the international search report
5 January 1994	17. 01. 94

Name and mailing address of the ISA	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+ 31-70) 340-2040, Tx. 31 651 epo nl, Fax (+31-70) 340-3016	Hageman, L

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C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT		
Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	EP,A,0 376 054 (ALLIGATOR VENTILFABRIK) 4 July 1990 see column 5, line 26 - line 37; figure 8 -----	5,9

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		JP-A-	1293209	27-11-89
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US-A-3710314	09-01-73	NONE		
DE-A-3714007	10-11-88	NONE		
EP-A-0376054	04-07-90	DE-A-	3843814	05-07-90